CVN 68 CLASS SOLID WASTE FLOW ANALYSIS

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Abstract

The US Navy has completed a detailed Research and Development Program to develop a suite of shipboard solid waste management equipment to enable compliance with federal and international law. Four major equipment's have been developed to outfit twenty-seven classes of naval ships. The major equipment types are: Plastic Waste Processor (PWP), Metal/Glass Shredder (MGS), Large Pulper (LP), and Small Pulper (SP). The Navy is now embarked on an aggressive effort to procure and install this equipment aboard all ships of FFG 7 Class and larger by 31 December 2000.

Engineering analysis and field waste generation studies were conducted to select the specific equipment suite and develop ship alteration documentation for each ship class. Specific drivers in this process were: solid waste generation rates, equipment reliability analysis, ship arrangement considerations, daily equipment operation limits, and shipboard quality of life factors.

A solid waste management study was conducted in the fall of 1997 to validate equipment and ship design parameters aboard the USS JOHN C. STENNIS (CVN 74). Determination of shipboard solid waste generation rates for: plastic, metal and glass, food, paper, cardboard, fabric and wood were made. The overall generation rate of 1.64 lb/person-day represents a 49% reduction in waste generation from the original design premise of 3.19 lb/person-day. The reduced generation rates may be due to a combination of solid waste reduction initiatives used by the ship, Navy Pollution Prevention initiatives, and economies of scale derived from a large warship with design complement of 6,286. Ship arrangement studies were also conducted to optimize the location of Solid

Waste Processing Rooms (SWPRs) relative to waste generation sites to most efficiently process the solid waste generated. The study recommendations for reduced equipment and number of SWPRs provides estimated life cycle cost savings of $97M for the CVN 68 Class.

The purpose of this paper is to articulate the process followed by the Navy in developing its response to regulations governing solid waste management in the marine environment. Evidence validating the engineering procedures followed is presented.

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Abbreviations/Definitions

AFP	Approval for Full Production
AIRLANT	Naval Air Force, Atlantic Fleet
AIRPAC	Naval Air Force, Pacific Fleet
Ave.	Average
Cap.	Capacity
CDNSWC	Carderock Division of the Naval Surface Warfare Center
CLCU	Closed Loop Cooling Unit
CMU	Compress Melt Unit
CO	Commanding Officer
CPO	Chief Petty Officer
Equip.	Equipment
ft^3/per-day	cubic foot per person per day
hr	hour
hrs/day	hours per day
Incin.	Incinerator
lb	pound(s)
lb/hr	pounds per hour
lb/per-day	pounds per person per day
LP	Large Pulper
Mach.	Machine
MGS	Metal/Glass Shredder
NAVMAC	Naval Manpower Analysis Center
NAVSEA	Naval Sea Systems Command
nm	nautical mile
Oper.	Operating
Proc.	Process(ed)
PWP	Plastic Waste Processor
S-2	Crew Galley and Mess Division
S-3	Ship's Store Division
S-5	Wardroom
S-11	CPO Galley and Mess Division
S-13	Hazardous Materials Minimization Center
SP	Small Pulper
SWPR	Solid Waste Processing Room
SWS	Solid Waste Shredder

Objective

The objective of this study was to collect data on the solid waste generated and processed in the solid waste management equipment aboard USS JOHN C. STENNIS (CVN 74) to determine solid waste generation rates; whether the ship's solid waste processing rooms are optimally located and contain the appropriate mix of equipment; and examine the utility of the Incinerator. This data would then be used to engineer the most cost effective solid waste management equipment suite for the CVN 68 Class which is in keeping with two of the eight NAVSEA Safety and Environment Strategic Goals: effectively integrating pollution prevention and safety into the design and life cycle of our ships and reducing total ownership cost of our products.

Introduction and Background

The Naval Sea Systems Command's (NAVSEA) "Solid and Plastics Waste Management Program Plan"[1] (a.k.a. the "Green Book") described the development, acquisition, and Fleet-wide installation of four pieces of solid waste management equipment intended to process all the solid waste generated aboard surface ships. These are the Large Pulper (LP), Small Pulper (SP), Metal/Glass Shredder (MGS), and Plastic Waste Processor (PWP). Each has been designed to handle a specific portion of the solid waste stream and have gone through extensive test and evaluation culminating in successful Operational Evaluations (OPEVAL) aboard USS GEORGE WASHINGTON (CVN 73) in 1994. Approval for Full Production (AFP) for the PWP was granted by a NAVSEA Acquisition Review Board in January 1995; AFP for the LP, SP, and MGS was granted in March 1995. Two contracts to manufacture PWPs were awarded in 1995; most surface ships are required by federal law to be outfitted with PWPs before 1 January 1999. Two contracts were awarded in November 1997 to manufacture LPs, SPs, and MGSs; most surface ships will be equipped with these machines prior to 1 January 2001. An accounting of this program can be found in a 1997 American Society of Naval Engineer's paper titled "Navy's Shipboard Solid Waste Management Program."[2]

The pulpers are designed to process paper, cardboard, and food waste; they also serve as a paper classified documents destructor. The waste material is fed into the pulper where it is mixed with seawater and ground up into small particles that are then discharged overboard via an eductor when greater than 3 nm from land. The LP has a mixed waste processing rate of 680 lb/hr; the SP can process 140 lb/hr of mixed waste. Historically, approximately 70% of the solid waste generated aboard ship is pulpable and most of this comes from the galley/mess areas.

The MGS shreds metal waste (primarily aluminum soda and #10 cans) into thin strips and fractures glass waste into pieces that will sink readily in the ocean. The shredded product is placed in burlap bags forming a non-buoyant package for overboard discharge when greater

than 12 nm from shore. The MGS has a machine processing rate of 600 lb/hr. Most of the metal and glass waste is also generated in the galley/mess areas.

The PWP processes all plastic waste (food and non-food contaminated) into stable, 20" in diameter and approximately 1.5" thick disks that are stored onboard for offload and disposal ashore. It is usually composed of two or more Compress Melt Units (CMUs) {ARS Class has only one}, a Closed Loop Cooling Unit (CLCU) for every two CMUs, and, in most installations, a Solid Waste Shredder (SWS), which can service up to 6 CMUs. The SWS is virtually identical to the MGS and shreds the plastic (at a rate of 80 lb/hr) prior to processing it in the CMU. Shredding breaks down large objects that wouldn't fit in the CMU, liberates trapped liquids and food waste, and homogenizes the plastic waste which results in better disk quality (i.e. a disk that retains its shape and does not fall apart) and a higher overall PWP processing rate. The CMU melts the polyethylene portion of the plastic waste (which is approximately 70% of all shipboard plastic waste) and provides the compaction force to make the disk. A CLCU is connected to the CMU, which quickly removes the heat from the disk so that the disk can be removed and handled after processing and also to increase the overall processing rate of the PWP. A PWP equipped with SWS can process approximately 10 lb/hr per CMU. Historically, approximately 50% of the plastic generated shipboard comes from the galley/mess areas; the other 50% comes from supply shipping and receiving activities, work centers, berthings, and heads.

USS JOHN C. STENNIS (CVN 74) is the first ship in the Fleet to be outfitted with all the solid waste management equipment developed by NAVSEA (SEA 03L). This equipment and the Vent-O-Matic Incinerator are installed in 6 SWPRs containing a total of 14 CMUs, 8 CLCUs, 3 SWSs, 2 MGSs, 2 LPs, 1 SP, and the Incinerator. The location of the SWPRs and the equipment they contain are shown in Table 1.

Table 1
USS JOHN C. STENNIS (CVN 74)
Solid Waste Processing Rooms

SWPR	Compartment	Solid Waste Equipment Installed
	Number	
#1	03-40-12-Q	1 SP, 2 CMUs, 1 CLCU
#2	2-84-8-Q	3 CMUs, 2 CLCUs, 1 SWS
#3	1-118-3-Q	1 LP, 2 MGSs
#4	2-152-2-Q	1 LP, 4 CMUs, 2 CLCU, 1 SWS
#5	1-220-3-Q	1 Vent-O-Matic Incinerator
#6	1-220-1-Q	5 CMUs, 3 CLCUs, 1 SWS

The generation of solid waste (particularly plastics) is well documented. The Carderock Division of the Naval Surface Warfare Center (CDNSWC) conducted numerous studies in the late 1980s and early 1990s [3-8] to support and optimize development of solid waste management equipment for the surface fleet. The PWPs, MGSs, LPs, and SPs being acquired by NAVSEA for Fleet-wide deployment represent the best available technologies for surface ship solid waste management and are a direct result of data gathered during the solid waste generation studies.

Collecting solid waste generation rate information is not an exact science and the data collected exhibited a lot of variability. This would be expected as the generation of solid waste is influenced by a variety of factors including ship operations, menu served, time of year, personnel onboard, area of operation, and the waste management strategies employed. In a solid waste survey, the sampling technique and the cooperation of the ship also influence the data collected.

The solid waste surveys formed the basis for the generation rates chosen as design values in the "Green Book."[1] These are shown in Table 2. Wood and textiles were not addressed by the "Green Book"[1] but are listed in Table 2 as they occur aboard ship and are germane to this study. The wood and textiles data came from the "Solid Waste Generation Survey Conducted Aboard USS CAMDEN (AOE 2)."[8] Generation rates are reported as lb/person-day (lb/per-day) or ft^3/person-day (ft^3/per-day).

Table 2
Solid Waste Generation Rate Design Values

Solid Waste Category	Generation Rate by Weight (lb/per-day)	Generation Rate by Volume (ft^3/per-day)
Food	1.21	0.03

Paper and Cardboard	1.11	0.19
Metal and Glass	0.54	0.05
Plastic	0.20	0.15
Wood	0.01	<0.01
Textiles	0.12	0.01
TOTAL	**3.19**	**0.43**

Approach

The Solid Waste Flow Analysis was conducted aboard USS JOHN C. STENNIS (CVN 74) from 18 - 31 October 1997. The study commenced at 0900 on the 18th as the ship got underway from Norfolk, Virginia and concluded 13.625 days later at 2400 on the 31st while the ship was operating in the Puerto Rican Operating Area. The ship was manned by a full crew complement including the airwing and was conducting workups to qualify them as the surge carrier.

The Solid Waste Flow Analysis survey team (shown in Figure 1) was composed of eight members including:

LCDR Stephen P. Markle, USN (Team Leader), NAVSEA 03L1B,
CAPT Robert Kingsbury, USNR, CO of Naval Reserve NAVSEA Detachment 1206,
CAPT Walter Malec, USNR, Naval Reserve NAVSEA Detachment 1206,
CDR George Aprahamian, USNR, Naval Reserve NAVSEA Detachment 1206,
LCDR Jeff Messier, USNR, Naval Reserve NAVSEA Detachment 1206,
ENS Robert Buckingham, USNR, Naval Reserve NAVSEA Detachment 419,
MMC Dave Behringer, USN, USS GEORGE WASHINGTON (CVN 73),
Mr. Sean E. Gill, GEO-CENTERS, Incorporated.

Figure 1
Survey Team {a.k.a. Trash Busters} (L to R): Mr. Gill, LCDR Messier, CAPT Malec, ENS Buckingham, CAPT Kingsbury, CDR Aprahamian, MMC Behringer, and LCDR Markle.

Six of the team members were assigned to a specific SWPR, each responsible for collecting data on waste that entered that room. The remaining two team members served as rovers, assisting and relieving team members assigned to the spaces as necessary, documenting the study with photographs, spot checking spaces for trash accumulations, and entering all data collected into a database program constructed with Microsoft Access.

Support was provided to the survey team from the Naval Manpower Analysis Center (NAVMAC). EMCM Scott Bell, USN and HTCS James Campbell, USN were onboard for the first week to collect preliminary data regarding the operation of the equipment to facilitate conducting a formal manpower analysis at a later date.

A weigh station was setup in each of the 6 SWPRs as shown in Figure 2. A hanging spring scale having a 200 lb capacity in 2 lb increments was supported from the overhead (usually with a C-clamp, clevis, and S-hook) and a heavy duty plastic tarp (6' x 8') with grommets every 2 feet was attached to the scale's hook through the 4 corner grommets to support the weight of the waste to be weighed.

Figure 2
Weigh Station in Solid Waste Processing Room #2

Date, time, waste type and weight, estimated volume, type of container the waste came in, division generating the waste and compartment the waste was generated in were the data collected by the study team.

Results and Discussion

Personnel Aboard

The ship's personnel manifest was checked each day to provide an accurate count of the number of personnel aboard. Even though the ship had a full crew complement, including full airwing, the maximum number of personnel onboard did not exceed 4,800. The actual number of personnel ranged from a low of 4,297 on the 18th to a high of 4,742 on the 23rd with an average of 4,624. This data is considerably less than the design crew complement of 6,286 but the NAVMAC personnel onboard indicated that it was consistent with non-wartime manning levels for this class. Subsequent to this study, Force Personnel Offices at AIRLANT and AIRPAC were contacted. They indicated that in peacetime, a deploying CVN 68 Class ship, with full air wing aboard, normally carries approximately 4,300 persons aboard. This data suggests that for solid waste equipment, the design complement could be lowered from 6,286 to 4,700 and be representative of typical full complement and still provide excess margin for error.

Solid Waste Generated

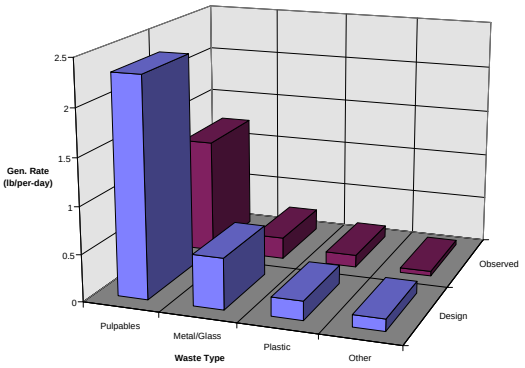
A total of 104,090.8 lbs of solid waste was weighed during the study. This included 21,958 lb of food, 35,317 lb of paper, 20,184 lb of cardboard (i.e. 77,459 lb of pulpable waste); 14,358.5 lb of metal and glass, 8,212.3 lb of plastic (61% was food contaminated), 344 lb of wood, 2,997 lb of textiles, 341 lb of mixed waste (largely cigarette butts and ashes from the smoking sponsons), and 379 lb of other waste (which was largely oily rags collected by the Hazardous Materials Minimization Center and should have been included in the textiles category which was also mostly rags). Because the crew size varied so much, the per capita generation rates were calculated on a daily basis and then averaged. Per capita generation rates are calculated by dividing the daily waste generated by the daily crew complement. Averaging the daily rates yields a per capita generation rate of 1.64 lb/per-day. The per capita generation rates for all the individual waste types by weight and volume (estimated) are shown in Table 3.

Table 3
Solid Waste Generated During the Solid Waste Flow Analysis Aboard USS JOHN C. STENNIS (CVN 74)

Waste Type	Weight (lb)	Estimated Volume (ft^3)	Gen. Rate (lb/per-day)	Gen. Rate (ft^3/per-day)
Food	21,958.0	1,308.5	0.35	0.02
Paper	35,317.0	6,314.5	0.56	0.10
Card-board	20,184.0	4,011.5	0.32	0.06
Metal and Glass	14,358.5	2,023.8	0.23	0.03
Plastics	8,212.3	2,547.0	0.13	0.04
Wood	344.0	41.0	<0.01	<0.01
Textiles	2,997.0	333.0	0.05	<0.01
Mixed	341.0	42.0	<0.01	<0.01
Other	379.0	40.0	<0.01	<0.01
TOTAL	104,090.8	16,661.3	1.64	0.26

This data shows that 74% of the waste generated by weight was pulpable, 14% was metal/glass and shreddable, 8% was plastic (and would be processed in the PWP) and only 4% (composed of wood, textiles, mixed, and other) was burnable. Obviously paper and cardboard are combustible but they are not considered "burnables" in this context. Burnable wastes are those that cannot be processed by any of the other solid waste management equipment. Figure 3 provides a comparison between design and observed solid waste generation rates.

Figure 3
Waste Generation Rate Comparison
(lbs/person-day)



USS JOHN C. STENNIS (CVN 74) had several significant solid waste management reduction strategies in place that reduced the overall generation of solid waste. Paper towels were not used in the heads; air hand dryers had been installed in their place. The Plan of the Day was only available on the ship's local area network, loose copies were no longer printed and distributed en masse. Copier use was greatly restricted by requiring the user to bring their own paper if more than one or two copies were wanted. Wooden pallets were stored for reuse or retrograde; pallets were metal banded rather than shrink-wrapped and the ship was reusing packaging material such as bubble wrap.

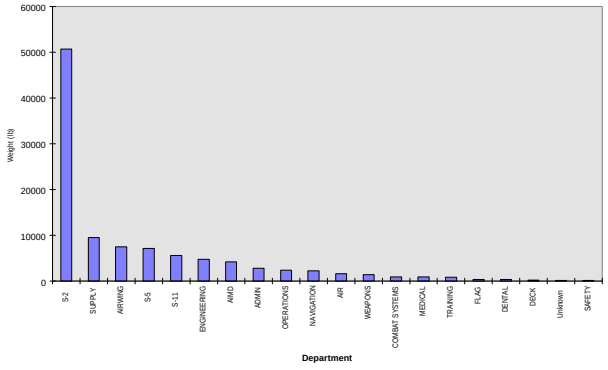
Wet strength paper bags were used extensively on the ship; 63% of the 6,214 waste deliveries recorded in the study came in a wet strength paper bag. While this may increase the amount of paper generated, it significantly lowers the quantity of plastic waste generated. Plastic bags were found to be the number 1 source of plastic waste on prior surveys.

The solid waste generation rate data collected from USS JOHN C. STENNIS (CVN 74) was reviewed by Desmatics, Incorporated[9] and statistically analyzed against the Navy's existing solid waste generation data from USS O'BANNON (DD 987),[4] USS DOYLE (FFG 39),[5] USS TEXAS (CGN 39),[6] USS LEXINGTON (AVT 16),[7] USS CAMDEN (AOE 2),[8] and USS PETERSON (DD 969). An analysis of variance found that while the overall and individual waste type generation rate data obtained from USS JOHN C. STENNIS (CVN 74) was lower than the previous data collected, only the food waste generation rate was statistically inconsistent with the previous data and "Green Book"[1] values. It is not fully understood why the food generation rates were so low. It could be due to most of the food waste being processed in the scullery garbage grinders or because the ship was not on station receiving fresh provisions. Desmatics, Incorporated's analysis stated that additional data would be necessary to statistically validate the inconsistent food waste generation rate and determine if overall generation rates on carriers are lower than other surface ships.

Solid Waste Origin - Departments

S-2 Division (Crew Galley and Mess) was the main generator of solid waste from a weight standpoint during the survey, producing 49% of the total waste surveyed. S-2 Division's total weight was more than 5 times that of the next closest generator, Supply Department. Supply Department as a whole, including the food service divisions (S-2, S-5, and S-11), which were considered separately, generated 70% of the total waste surveyed. The Airwing Department, which included all squadrons, was the next largest generator at 7% of the total solid waste weighed. The solid waste generated by weight in each of the 21 departments/divisions is presented graphically in Figure 4.

Figure 4
Total Weight of Solid Waste Generated by Department

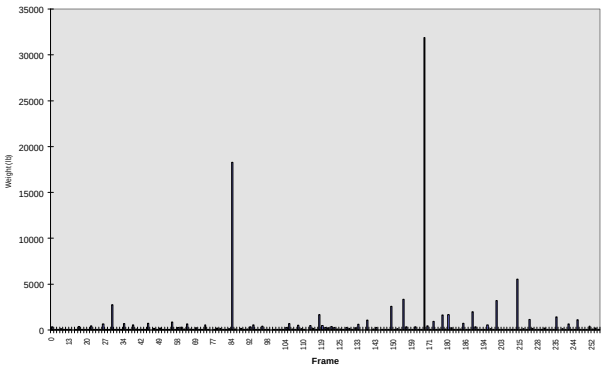


Solid Waste Origin - Compartment

The compartment the waste originated in was recorded so that the location of each SWPR relative to the waste generation sites could be evaluated; this also allowed determining where to best site the solid waste processing rooms. A total of 445 different compartments were

identified as generating waste during the survey. To simplify data analysis, the compartment numbers were truncated to their frame number only. The types and groupings (e.g. pulpable, etc.) of solid waste and the total quantity generated by weight was then plotted against frame number to identify peak generating locations over the length of the ship. Regardless of waste type or grouping, almost every graph showed the greatest generating site along the ship at frame 165. This is the location of the Aft Crew Galley and Mess and where most of the S-2 Division waste came from. The only exception to this was for textiles, other, and the burnable waste grouping. These plots showed frame 156 as the major generating site; this is the location of S-13 Division's Hazardous Material Minimization Center. Spikes on the plots were also seen at frames 29, 84, 148, 200, and 210. These represent Wardroom 1 and 2, Forward Crew Galley and Mess, S-3 Division's Ship Store and vending machines; Wardroom 3; and CPO Galley and Mess, respectively. Figure 5 shows the generation of all solid waste by weight over the length of the ship.

Figure 5
Total Weight of Solid Waste Generated Over
Length of the Ship (18 - 31 October 1997)

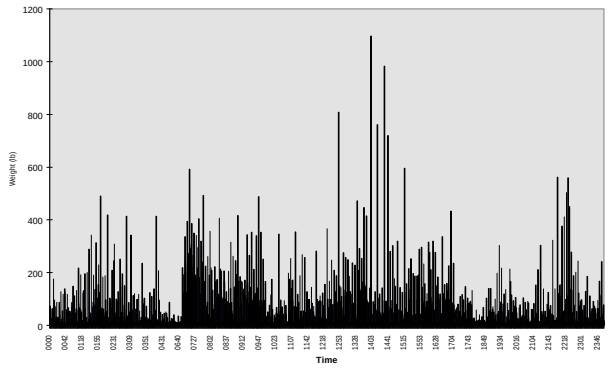


Solid Waste Generated by Time of Day

The time that the waste was delivered to each SWPR was also recorded. The weight of waste surveyed during the study period was then summed by delivery time and plotted to determine when the peak delivery times occurred overall, for each waste type and grouping, and in each SWPR. The total solid waste generation plot by weight over time of day is shown in Figure 6. Peaks in the overall generation data are clearly seen from approximately 0100 - 0430; 0700 - 1000; 1230 - 1700; and 2100 - 2400. These times roughly coincide with midnight rations, breakfast, lunch, and dinner, although the dinner peak appears to have been pushed back by several hours. This is likely due to General Quarters drills that were usually held from 1930 - 2130 each day for the first 9 days of the survey.

The burnables waste grouping was not tied to mealtimes. It appears to be tied to the time when the Incinerator was open for operation although most of the waste was burned in the early hours of the morning between 0000 and 0330. The fact that the Hazardous Materials Minimization Center choose to deliver all their oily rags and textiles at night largely explains the heavy usage between 0000 and 0330. Wood and mixed waste appeared throughout the day at random.

Figure 6
Total Weight of Solid Waste Generated
Throughout the Day (18 - 31 October 1997)



Solid Waste Processing Equipment Usage

The operating hours or the number of disks produced, as appropriate, were recorded from each machine at midnight each day. This was done so that the average processing rates and equipment usage could be determined. Equipment operating hours were read from the hour meter; for the CMUs, operating hours were calculated by multiplying 40 minutes (the average disk cycle time) by the number of disks produced from that space. The average daily waste processed was determined from the total quantity of waste brought to that space that would be processed in that particular type of machine and then divided by the total number of days of the survey (i.e. 13.625 days). Average daily waste processed was then divided by average daily operating time and the number of like machines in the space to get an average processing

rate which was compared against the machine's rated processing rate to get an equipment usage figure in percent of full rated capacity. Because the crew rarely used the SWSs, and no record was kept of actual operation, it was not possible to determine or even estimate process rates. Similarly, because the Incinerator is not equipped with an hour meter and a log of actual operating time was not maintained, the average operating hours per day have been estimated as 14 hrs/day. The scheduled operating time for the Incinerator was 16 hrs/day but several underway replenishments and general quarters drills reduced the actual operating hours accordingly. The data on average processing rates and equipment usage is presented in Table 4. The average daily operating time listed is for all the like equipment in that space; it is not a per machine average.

Table 4 shows that none of the CMUs in any of the SWPRs, on average, were being operated at capacity (i.e. 10 lb/hr). This was largely due to the operators not using the SWSs and loading only a small amount of plastic into the machines to make a disk.

The average pre-processed weight of the 1,163 disks made during the survey was approximately 7 lb (i.e. 8,212.3 lb of pre-processed weight/1,163 disks). Since all of the disks were not weighed after processing an actual average disk weight cannot be reported. This average weight could have been improved upon significantly if the SWSs were being used.

Neither of the LPs was operated near its full rated capacity mainly because the operators started the machines at the beginning of the shift and let them run continuously whether there was trash to process or not. During peak delivery times the pulpers were often operated at or above capacity but not as an average. The same is true of the SP even though its capacity number was much higher. The SP's higher capacity number was due to a more effective use of the machine, a much smaller processing rate compared against the LP, and the SWPR it was installed in being open for only 12 hrs/day.
The 2 MGSs in SWPR #3 processed all the metal/glass waste generated during the survey (including aluminum soda cans) in an average of only 1.3 hours of motor operating time per day for the pair. This equates to a processing rate of 405.5 lb/hr per machine, that is 67.8% of the design machine processing rate.

Table 4
Average Solid Waste Management Equipment
Processing Rates and Usage

SWPR	Equip.	Ave. Daily Oper. Time (hr)	Ave. Daily Waste Proc. (lb)	Ave. Proc. Rate per Mach. (lb/hr)	Usage (% of Full Rated Cap.)
#1	SP	5.1	339.5	66.7	47.6
#1	2 CMUs	2.9	31.9	5.5	55
#2	3 CMUs	11.3	97.4	2.8	28
#3	LP	15.2	999.5	65.8	9.7
#3	2 MGSs	1.3	1,053.8	405.3	67.6
#4	LP	17.1	3,156.6	184.6	27.2
#4	4 CMUs	23.7	260	2.7	27
#5	Incin.	14	1,495.2	106.8	21.4
#6	5 CMUs	17.5	205.9	2.4	24

The Incinerator was operated at approximately 21% of its rated capacity but in contrast to the pulpers, it was greatly over utilized. Approximately 79% or 16,207 lb of what was processed in the Incinerator was pulpable and should have been processed in one of the 3 pulpers; another 1% was plastic. If only the burnable wastes (i.e. textiles, mixed, wood, and other) were processed in the Incinerator, it would have operated but 41 hours over the two week survey period at its observed processing rate. This breaks down to approximately 3 hr/day of operating time (excluding cool down and ash removal). When these latter arduous tasks are considered, it becomes very appealing and practical to only operate the Incinerator every other or every third day. This practice would also significantly extend the lifetime of the Incinerator by eliminating premature failure of the refractory and significantly lower life cycle costs.

Evaluation of Solid Waste Processing Rooms

An objective of the study was to make an assessment on the suitability of the location of the SWPRs selected and their mix of equipment. This was determined by analyzing the data collected at each room and through observation.

SWPR #1 was given a rating of fair. Sufficient waste was generated forward to warrant an installation at this frame and the mix of equipment was proper. However, this space should be located as close to the primary generator of waste in the area as possible and that area is Wardroom 1 and 2; the most effective location would be adjacent the Wardroom 1 and 2 Scullery. That was not the case on

CVN 74; the scullery being located starboard and SWPR #1 being located on the port side.

SWPR #2 was also rated fair. Its location is ideal for processing all plastic waste generated by the Forward Crew Galley and Mess. Approximately 12% of all the plastic waste came from Frame 84 (Forward Crew Galley and Mess) and almost 2,100 lb of plastic (25% of the total) was generated between frames 51 and 110. However, ships force opted to operate the equipment in this space only sparingly due to mess deck queuing, and desire to centrally process all food contaminated plastic in SWPR #4.

SWPR #3 received a rating of poor. Several heavy watertight doors must be opened to reach the space and operation at night is in violation of darken ship requirements. Heavy and cold weather conditions have the potential to make operations in, and transit to this space hazardous. The space must be closed during underway replenishment because it is adjacent a refueling sponson and there is no discharge chute to discharge processed and bagged metal/glass. Shredded material is transported on a cart through Hangar Bays 2 and 3 to the discharge chute in SWPR #5 presenting a potentially significant FOD hazard.

Approximately 4,515 aluminum soda cans were generated each day onboard USS JOHN C. STENNIS (CVN 74) with an average weight of 116 lb. This data was based on the average number of soda cans stocked into the soda machines each day. This indicates that approximately 15% of the weight processed by the MGSs was aluminum soda cans. Ship's force is considering an aluminum can recycling program to supplement Morale, Welfare, and Recreation funds. If implemented, this would remove a high volume portion of the material that must be shredded from this particular ship.

SWPR #4 was the best sited space on the ship and was given a rating of good. It was located near the largest generator of waste on the ship (i.e. the Aft Crew Galley and Mess), had a favorable mix of equipment, and was out of the main traffic flow through the Aft Crew Galley and Mess area. Approximately 31% of the total solid waste generated during the survey originated only 13 frames aft of this space and 86% of that waste could be processed by the equipment in this space. If one of the MGSs had been installed in this space (with a nearby discharge chute) the space location and equipment mix would have been perfect. However, ship class/design managers have indicated that it is not practical to install a discharge chute in a location convenient to this space.

SWPR #5 was not rated but the Incinerator was deemed a valuable asset to this ship because it could process the materials that the other solid waste management equipment could not. This included the burnable grouping of wastes (i.e. mixed, other, wood, and textiles) which represented 4% (4,163 lb) of the waste weighed during the survey. The Incinerator was also used to burn non-pulpable classified documents, maps, and charts.

SWPR #6 was given a rating of fair mainly because the equipment mix did not adequately support the waste generated in that part of the ship. This space should have had the LP from SWPR #3 installed in it and the 5 CMUs that were installed provided more than twice the processing capability required for this part of the ship. Analysis of the plastic waste generation potential aft of frame 190 showed that only 1,991 lb of plastic was produced; 56% was processed in SWPR #6. This quantity of plastic could be processed effectively by 2 CMUs.

Solid Waste Processing Room Recommendations

The present configuration of SWPRs onboard USS JOHN C. STENNIS (CVN 74) are not optimized for the CVN 68 Class based upon the data collected in this survey. An optimized system would site the rooms near the major waste generating locations and ensure the necessary equipment was installed in the space or spaces. An optimized system would place a major solid waste processing center (including a LP, PWP, and an MGS - with a suitable and closely located discharge chute) adjacent the Forward Crew Galley and Mess and the Aft Crew Galley and Mess and install smaller processing spaces further forward and aft (near Wardroom 1 and 2 Scullery and the Incinerator Room are acceptable locations); and it would retain the Incinerator. The smaller forward space should contain a SP and 2 CMUs; the aft space should have 2 CMUs and a SWS. The forward waste processing center should contain 2 CMUs and a SWS and the aft waste processing center should have 4 CMUs and a SWS. Each processing center has an MGS for the convenience of the operators and crew. This results in a total equipment suite of 10 CMUs, 3 SWSs, 2 LPs, 2 MGSs, 1 SP, and the Incinerator. More CMUs are needed to support the design crew size (6,286) given the established design values and assumptions but this configuration could reliably support crew complements of up to 4,700 persons. Each of the 4 SWPRs would operate

for 3 hours immediately following each meal for a total of 12 hrs/day; the Incinerator would only be run every third day. Such a system would put processing equipment where it is needed most (adjacent to the galley and mess areas) while providing the capability to process all waste groupings (except burnables) within approximately 80 frames of any spot on the ship.

Design, schedule and fiscal realities make it unlikely that the optimum configuration will ever be installed on a CVN 68 Class ship. Most ships of the class have or shortly will receive their PWPs and cannot fully benefit from the results of this study but several ships still can and for them, an alternative option is offered. The equipment in SWPR #1 should be retained but installed adjacent to or very near the Wardroom 1 and 2 Scullery. Retain SWPR #2. SWPR #3 should be abandoned: its LP should be installed in SWPR #6 that should be reduced to 2 CMUs and a SWS to accommodate the LP; 1 of the MGSs should be installed in or near SWPR #5. Retain SWPR #4. This gives a total equipment complement of 11 CMUs, 3 SWS, 2 LPs, 1 MGS, 1 SP, and the Incinerator in 5 spaces. Like the optimum configuration above, this system can only support crew sizes up to 4,700 persons using the established design values and assumptions. Installing one of the MGSs in or near the Incinerator room places it adjacent to the discharge chute and since the Incinerator will only have to be run occasionally, a schedule can be developed to avoid operational conflicts. Exclusive of the Incinerator, the spaces need only be operated 12 hours per day for 3 hours after the 4 mealtimes; the Incinerator should be operated every third day from approximately 0000 to 0700.

Both of the above configurations are predicated on the established Navy design values and assumptions but with a reduced crew complement of 4,700 persons. There is additional data available on post-processed plastic waste generation from USS GEORGE WASHINGTON (CVN 73), USS ABRAHAM LINCOLN (CVN 72), and USS JOHN C. STENNIS that can be considered. Ship's force collected this data by weighing 69,221 lb of PWP disks produced by these three ships while underway for a total of 175 days. This data reduces to a PWP post-processed plastic waste generation rate of 0.10 lb/per-day. There is no established relationship between pre-processed and post-processed plastic waste generation data. Although, this data cannot be used to form a statistical argument for changing the Navy plastic waste design generation rate, engineering judgment easily allows a rate of 0.15 lb/per-day. Available data indicates that this is a reasonable plastic waste generation rate for ships of the CVN 68 Class. In this context the generation rate is only applicable to the CVN 68 Class and to no others. Using this generation rate with other design parameters of mission duration, reliability/availability/maintainability, machine processing rate results in 11 CMUs with the design crew complement of 6,286 and 9 CMUs with a reduced crew complement of 4,700. Between 9 and 11 CMUs are sufficient to reliably process the plastic waste onboard a CVN 68 Class ship given a plastic waste generation rate of 0.15 lb/per-day. The optimum arrangement taking into account generation location, design and cost of solid waste management equipment for the CVN 68 Class can be found in 10 CMUs, 5 CLCUs, 3 SWS, 2 LPs, 1 SP, and 1 MGS. This combination optimizes the CMU to CLCU ratio and fits into 4 existing spaces (i.e. SWPRs #1, #2, #4, and #6).

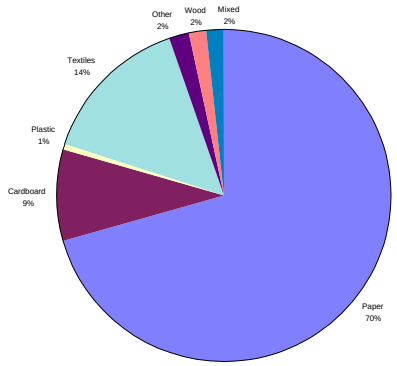
Incinerator Usage

The Incinerator processed 20,372 lb of solid waste during the study. However, 79% of this waste was pulpable (either paper or cardboard) and should have been diverted to one of the 3 pulpers onboard for more effective processing of the waste; another 1% was plastic. Modification of the design to include an LP aft should minimize burning of pulpables. The remaining 20% of waste processed was composed of wood, textiles, mixed, and other. These waste categories cannot be accommodated by the NAVSEA solid waste management equipment and should be processed in the Incinerator. The average daily Incinerator throughput is given in Table 5. The breakdown of waste processed by the Incinerator is shown in Figure 7

Table 5
Daily Incinerator Throughput

Waste Stream	lbs/day
Pulpables	1,190.0
Plastics	7.6
Wood	25.3
Textiles	220.0
Other	23.2
Total	1,466.1

Figure 7
Breakdown of Solid Waste Processed by the Incinerator



Conclusions

1. The overall observed solid waste generation rate was 1.64 lb/per-day, 51% of the design rate. This data is a snapshot of one ship operating off the coast of North America for a two week period in the fall of 1997. The data may be representative of all CVN 68 Class ships operating in other parts of the world at different times.

2. Despite the low observed generation rates, an analysis of variance of the primary constituents (i.e. food, paper/cardboard, metal/glass, and plastic) indicated that only the rate observed for food waste was statistically inconsistent with previous studies. Additional data is necessary to statistically verify that generation rates on carriers are lower than other surface ships.

3. Data available on post-processed plastic waste generation from several CVN 68 Class ships supports use of 0.15 lbs/per-day as a reasonable design plastic waste generation rate for this class only.

4. The design manning for CVN 68 Class is given as 6,286. This survey, discussions with NAVMAC personnel, and data received from AIRLANT and AIRPAC indicate that a reasonable design may be based on a crew size of 4,700.

5. Applying a reduced plastic waste generation rate (i.e. 0.15 lb/per-day) and a reduced manning level results in the minimum number of CMUs and MGSs required for the CVN 68 Class: 9 CMUs and 1 MGS. Effective processing of the solid waste generated by this class can be achieved with a total equipment suite of between 9 and 11 CMUs, 5 - 6 CLCUs, 3 SWSs, 2 LPs, 1 SP, 1 MGS, and the Incinerator. The optimum arrangement balancing design, cost and processing efficiency for the CVN 68 Class is shown in Table 6 below.

Table 6
Recommended CVN 68 Class Equipment Mix

New SWPR	Existing SWPR	Equipment Mix
1	1	1 SP, 2 CMUs, 1 CLCU
2	2	2 CMUs, 1 CLCU, 1 SWS
3	4	1 LP, 4 CMUs, 2 CLCUs, 1 SWS
4	6	1 LP, 2 CMUs, 1 CLCU, 1 SWS
5	5	1 MGS, 1 Incinerator

6. The CVN 68 Class solid waste management suite is not installed in optimum locations aboard ship, nor does it contain the appropriate mixes of equipment. The Forward and Aft Crew Galley and Mess areas generated the majority of the waste observed during the survey and a solid waste processing center (containing a LP, PWP, and MGS) should have been installed to support each. Smaller and less capable SWPRs should have been installed further forward and aft (near Wardroom 1 and 2 Scullery and the Incinerator Room).

7. Future carrier designs should concentrate solid waste equipment around the crew mess decks. Smaller satellite suites should be strategically located to minimize internal transport of unprocessed waste.

8. An Incinerator is a useful addition to the NAVSEA solid waste management equipment on a ship of this size, as it can process solid wastes (i.e. textiles, wood, mixed, and other) the NAVSEA equipment cannot. However, it should only be used to process waste characterized as "Burnable."

9. A conservative, rough order of magnitude estimate of cost savings to the Navy due to the reduced life cycle costs of installing less solid waste management equipment on the CVN 68 Class as a result of this study are $97M over the remaining lifetime of the nine ships affected. This estimate takes into account acquisition and installation costs and the manpower savings associated with operations and maintenance.

Acknowledgments

It is always easier to critique the work of those that have gone before. Credit is given to the team that designed the USS JOHN C. STENNIS (CVN 74) Solid Waste Management Equipment Suite. The insertion of pulpers and shredders into the design at the last possible moment in the ship construction process (during PSA) is a testament to the vision of this team. Unfortunately, location alternatives for this equipment were minimal, their options few. The purpose of this study is not to condemn, but rather to applaud and evaluate what was achieved, so as to make changes, where change can be made to deliver to the Fleet the most efficient yet cost effective solution possible.

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The real story of this survey was the high degree of cooperation between the Naval Reserve Force, AIRLANT, NAVMAC, PMS 312, NAVSEA, and crew of USS JOHN C. STENNIS (CVN 74) in pulling the team together. Thanks to this partnering, and the teamwork displayed by all participants, achievement of a more realistic solid waste management suite design based on current and anticipated future operational profile of the CVN 68 Class has been accomplished.

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